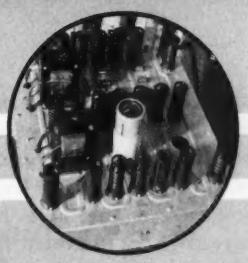
Vol. V, No. 4, Winter 1958



research trends

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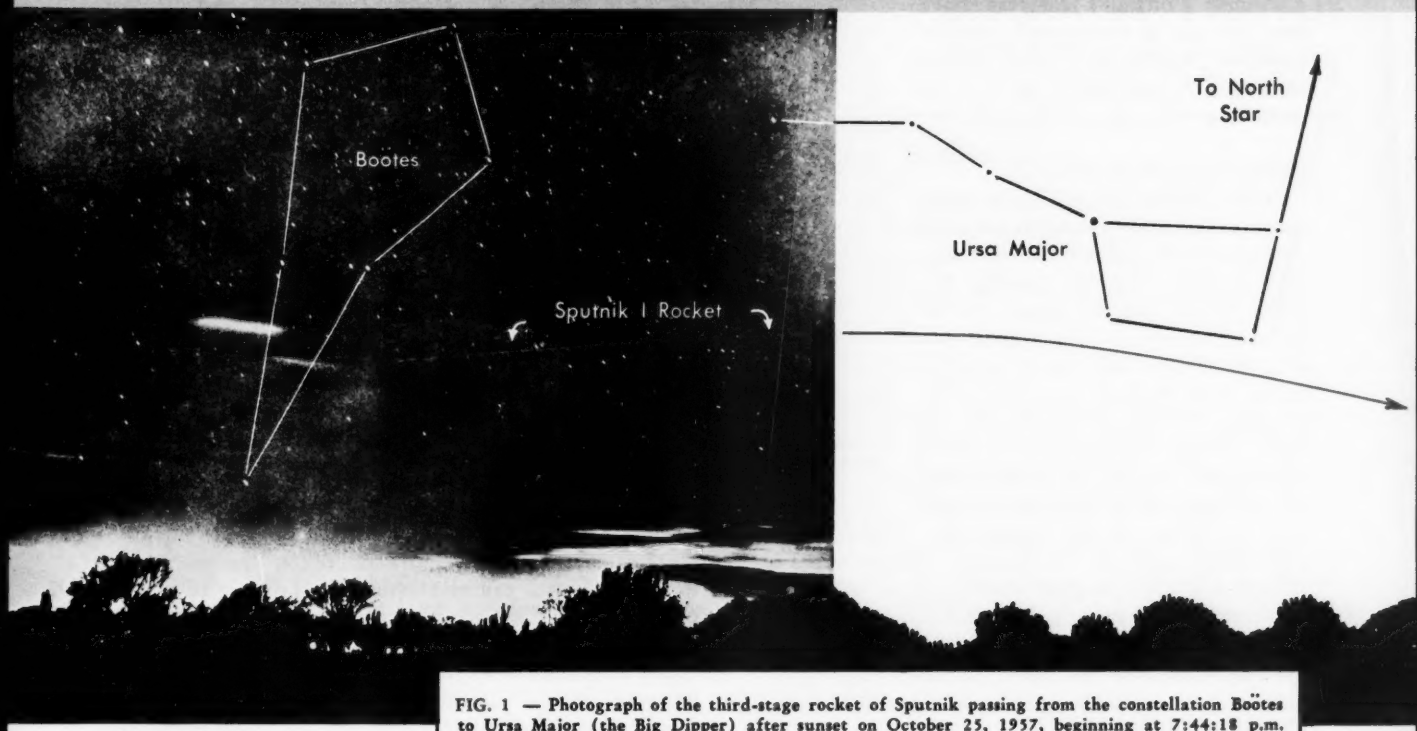

A LogEtronics Print

FIG. 1 — Photograph of the third-stage rocket of Sputnik passing from the constellation Boötes to Ursa Major (the Big Dipper) after sunset on October 25, 1957, beginning at 7:44:18 p.m. Eastern Daylight Time. The blanks in the trace are caused by a rotating shutter in front of the lens used to obtain timing marks at one second intervals. The rocket was about 425 miles away. The photograph was taken at f4.5 on Royal X Pan. The trace through the stars is not retouched, though considerable "dodging" was required to compensate for the somewhat cloudy western sky that was not yet uniformly dark.

Satellite Summary

by SEVILLE CHAPMAN

The United States Army, at this writing, has just successfully put its Explorer satellite into orbit, following the Soviet Sputniks. It is quite likely that by the time you read these words there will be other satellites orbiting.

In 1955 not many of us knew that when the White House announced our intention to launch such a moon as part of the scientific program of the International Geophysical Year, the Russians had already beaten us to the punch with a similar announcement. Perhaps we ignored the Russian announcement because it was then fashionable to attribute technological backwardness to the Soviets. Since then, however, many people have seen the Sputniks and have become aware of their considerable propaganda value. Similarly, we have seen a big swing in international moods and feelings following the Explorer launching.

But what are man-made satellites good for as part of a scientific program? Further, what are they, how do we see them, and what is their significance?

Inert Satellites

Accurate observations of the orbit of an inert satellite yield information about the distribution of material inside the earth, since slight gravitational irregularities can be inferred from the orbit. Present information comes partly from our own moon, which is much farther away, and hence not so sensitive to these effects. Careful sightings on a satellite from stations on different continents can improve the accuracy with which the relative positions of continents are known. At present the uncertainty in the location of Europe relative to America is of the order of a thousand feet — a significant error for an intercontinental missile. Although

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the earth's atmosphere at satellite altitudes is so tenuous as to be considered an excellent vacuum by laboratory standards, it exerts a retarding force on satellites. Measurements already have indicated that the upper atmosphere is about five times as dense as was previously thought. Elaborate "official" cameras have been set up to photograph satellite positions accurately, and many volunteer "Moon-watch" groups observe with low-power telescopes.

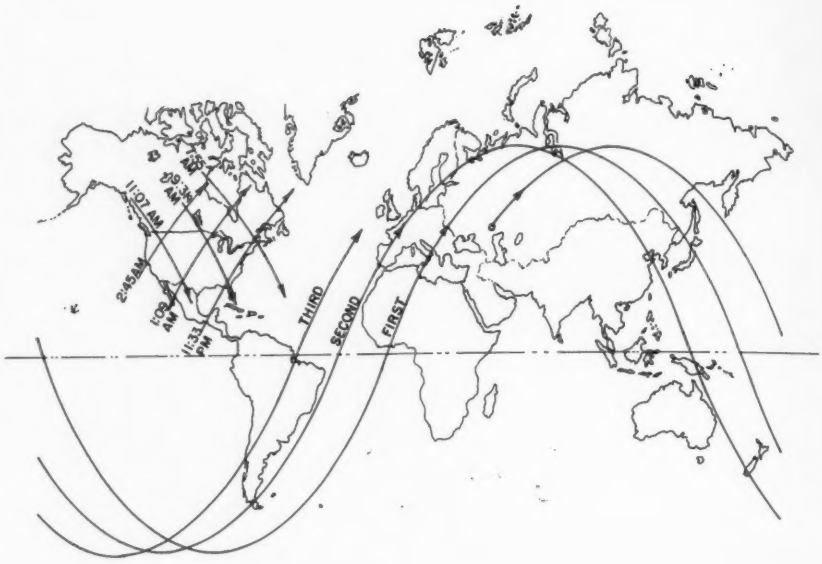


FIG. 2 — Mercator map showing the first three orbits of Sputnik. The orbit remains nearly fixed in space while the earth turns underneath the orbit, 24 degrees in one period of about an hour and a half. Times are given in Eastern Daylight Time for the first passes over the United States 4-5 October. Note that near any point, including your city, there will be four passes a day, two northeast and two southeast.

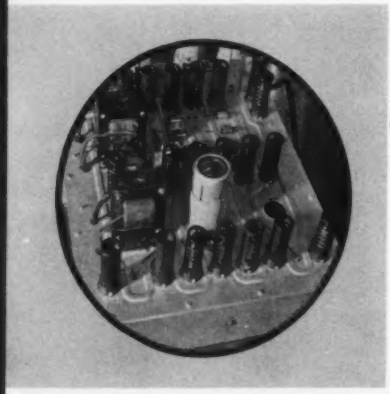
Radio-Equipped Satellites

If the satellite carries a radio transmitter, then precise measurements of the apparent frequency can be made. The satellite is moving rapidly. Because of the Doppler effect, its apparent frequency will be higher as it is approaching, and lower as it recedes from a given receiver. This Doppler shift can be allowed for by fairly simple straight-forward calculations, but further small deviations can be expected because of propagation conditions in the ionosphere. These deviations yield information on the electron density in the ionosphere, a matter of great theoretical, as well as practical, importance in long distance radio communication. Again, elaborate official "Mini-track" radio tracking stations have been set up.

Instrumented Satellites

If the satellite carries some elementary instrumentation one can measure such things as meteoric erosion, cosmic rays, and ultraviolet radiation from the sun. If the instrumentation is more elaborate, the magnetic field of the earth can be measured in a matter of hours over the whole surface of the earth from a sufficient distance to be away from local surface irregularities. Thus, information about the interior of the earth can be secured from satellite measurements. It is interesting that the best instrument for this astronomical-interior-of-the-earth measurement is the proton magnetometer, a new atomic device. Measurements can be made from above the atmosphere of the solar energy falling on the earth, its reflectivity, and the heat balance. Ultraviolet radiation of wavelength less than 2900 Angstroms (0.00002900 centimeters) is absorbed in the upper atmosphere and produces ionizing and chemical reactions there. Except for a few moments of rough measurements from rockets, the intensity of the hydrogen Lyman alpha line at 1215 Angstroms has only been inferred, but it can be measured continuously from a satellite. This information would be of great interest during solar flares. With even more elaborate instrumentation, for example long-range high-resolution TV, one could see the weather pattern over the whole world within a matter of hours. Such observation would materially improve the understanding of weather, particularly in the ocean areas which are infrequently traveled. Possible military surveillance by such means has been alluded to many times in the press. A large satellite of course could be a platform for an astronomical observatory with virtually zero atmospheric interference.

The theory of relativity says that time runs more slowly for a very rapidly moving object than for an object at rest. The difference is not significant for



THE COVER

The liquid cooled chassis undergoing thermal analysis has integral coolant flow passages to reduce the temperature rise between the hot electronic parts and the coolant. This chassis is representative of future equipments which must meet the ever increasing need for greater power dissipation and higher operating temperatures, without heating the adjacent equipment or surrounding spaces. At 600 watts dissipation, this technique limited the hot spots on the electron tube bulbs to less than 60°C above the coolant temperature. All electronic heat producing parts were provided with direct metal heat flow paths to the coolant. The purpose of this test is to determine the thermal performance of typical future equipment under varying powers, coolant flow rates, and temperature. These data will be incorporated into design manuals to be used by electronic engineers in future equipment designs.

travel within the solar system as a practical matter, but if propulsion-energy sources are ever developed suitable for travel outside of the solar system, one might spend twenty earth-years on such a trip and return only ten years older. At the present stage of development an atomic clock might just detect this time dilatation effect on an earth satellite, if such a clock could be put into a satellite. It will probably be several years, however, before such clocks and satellites will be compatible.

Perhaps the most fascinating commercial application for satellites would be one 22,000 miles above the equator. The satellite would complete one pass around the earth in exactly the same time that it takes the earth to turn around once — 24 hours — and hence would remain over the same spot for decades. As a radio relay station, or as a TV transmitter location, it could cover an entire hemisphere continuously. A group of a dozen or so large satellites might be used rather effectively to jam a radar defense network.

Obviously there are many more things that can be done — satellites open up completely new fields of science and technology.

Calculating the Orbit

It is easy to calculate the orbit speed of an earth satellite from a relation in any high-school physics book. A satellite travels in an approximately circular orbit with the center of the earth near the center of the circle. Any orbiting satellite is continuously falling toward the center of the earth, and (except for a correction mentioned in the next paragraph) falling with the same acceleration as any ordinary object, such as a baseball being hit over the fence for a home run. For an object traveling in a circular path, the acceleration toward the center is velocity squared divided by radius, thus $A = v^2/r$, or $v^2 = Ar$. The difference between the satellite and the baseball is that the speed of the baseball is relatively small so that it falls back to earth, whereas the satellite must go fast enough so that when it has fallen appreciably it has traveled far enough for the earth's surface to have curved away from under it sufficiently to keep it the same distance above the ground, its centrifugal force being just balanced by gravity. For the baseball or a satellite near the earth's surface, the acceleration (or rate of change of velocity) is 32 ft/sec per second, or 32/5280 miles/second^2. The radius of the earth is about 3960 miles, which we will call 4000 miles. Thus $v^2 = \frac{32}{5280} \times 4000 = 24.2$, and the velocity for an orbit is about 4.9 miles per second.

There would be too much heating due to air resistance close to the surface of the earth for a satellite to exist, so that if we consider a satellite 350 miles up (4350 miles from the earth's center) as was the case with the first satellite, then by Newton's inverse-square-law of gravity, the acceleration will be $\frac{32}{5280}\left(\frac{4000}{4350}\right)^2$ miles/second^2. The orbit speed then is about 4.7 miles per second (i.e. less at higher altitudes). Dividing the circumference of the orbit by the speed gives the period, or time to make one revolution, about 5800 seconds or 96 minutes. These results can hardly be considered new or classified — they were known in the seventeenth century.

At such speeds any object going through the lower atmosphere would burn up, so that in launching a satellite it is necessary to lift it up out of the dense part of the atmosphere before giving it most of its speed.

Launching the Satellite

Ideally in a rocket launching system one would choose a minimum of rocket structure and a maximum of fuel, and would arrange to jettison empty tanks as soon as possible in order to eliminate unnecessary weight. The requirement of getting propulsion from the fuel dictates that a rocket have an appropriate combustion chamber and high temperature exhaust jet. In principle an infinite number of small stages, each jettisoned when used up, would be most efficient, but as a practical matter, considering the weights of fuel tanks, pipes, pumps, exhausts, etc., a rocket of three or four stages seems most suitable.

Our Explorer satellite is a 6-inch cylinder, 80 inches long, launched from an Army Jupiter-C missile. Our

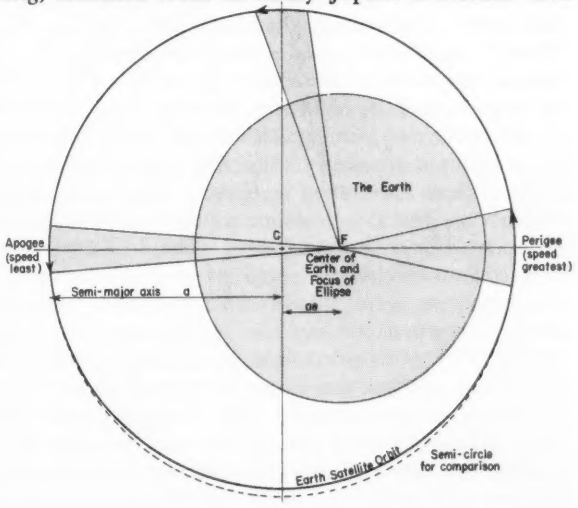
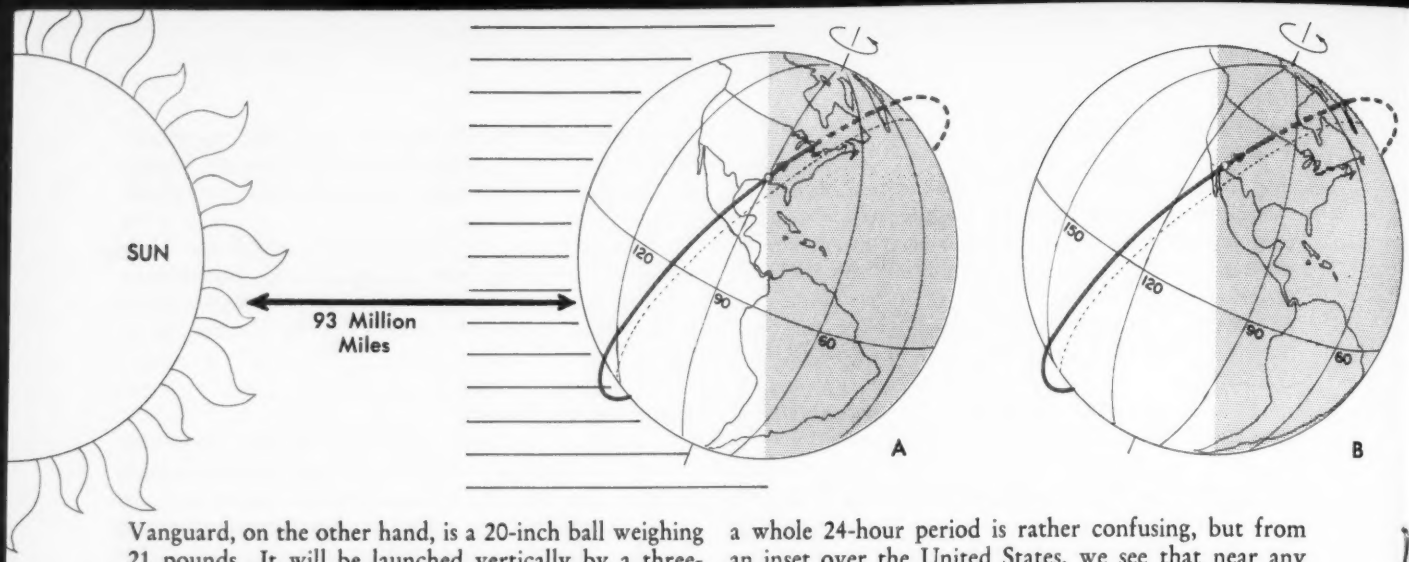


FIG. 3 — Earth satellite elliptical orbit. The focus F of the ellipse is at the center of the earth. The speed is greatest at position of perigee and least at position of apogee (exact relations can be determined from one of Kepler's laws which says that the rate of sweeping out of area by the radius vector is constant — thus the areas of the three shaded triangles are the same). The eccentricity "e" of this orbit is about twice that presently contemplated for any earth satellite (and apogee is much too far away), but even so, the orbit still is almost circular, the center of the ellipse being at "C".

There are six elements of an earth-satellite elliptical orbit: its semi-major axis "a", its eccentricity "e", the right ascension of the ascending node (angle seen from the earth's center between the point in the sky known as the vernal equinox and the point where the orbit crosses the equator going north) Ω, the angle of inclination of the orbit to the equator "i", the argument of perigee (angle between the ascending node and point of perigee) ω, and the time of perigee passage "T". The first two define the size and shape of the ellipse, the second two the orientation of the plane of the ellipse, the fifth the orientation in the plane, and the last the time. Implicit as a seventh element is the requirement that the focus of the ellipse be at the earth's center, thus corresponding to the seven data required for specifying an orbit — three position components, three velocity components, and time. Deviations from this simply described orbit provide scientific information.



Vanguard, on the other hand, is a 20-inch ball weighing 21 pounds. It will be launched vertically by a three-stage rocket 72 feet long and 45 inches in diameter, whose total weight when loaded with fuel is 22,000 pounds. The average thrust of the first stage powered by kerosene and liquid oxygen is 27,000 pounds. As the fuel burns away the weight decreases and the acceleration increases. At a height of 35 miles and at one fifth of final speed, the spent first stage is jettisoned to avoid having to accelerate now-useless weight, and the second stage powered by nitric acid and hydrazine takes over. The total weight is now 2400 pounds. At an altitude of 130 miles and at half the final speed, the second stage fuel is exhausted. The rocket then coasts up to an altitude of 300 miles, slowing down somewhat in the process of gaining altitude and at the same time going into a more nearly horizontal trajectory. At 300 miles altitude the rocket levels off. The second stage, which contains the guidance equipment, orients the final stage before dropping away. The final stage solid-fuel rocket brings the speed of the remaining 270 pounds up to about 17,500 miles per hour. The 21-pound instrumented satellite is separated from the rocket with a trivial 3 feet per second speed. The separation enables the instruments and radio transmitter to operate properly. The launching procedure takes 10 minutes and carries the satellite about 1000 miles. This final speed is a bit greater than necessary for a circular orbit, and hence the orbits are somewhat elongated or elliptical.

To get a satellite into an orbit requires energy for lifting it (potential energy), and energy for speed (kinetic energy). For typical orbits, the required kinetic energy is perhaps twenty times as great as the potential energy so that launching is primarily a matter of speed, not of lifting.

For down-range tracking, our satellites and test missiles are launched southeast from Florida over a group of islands stretching several thousand miles toward South Africa. The Russians launch their satellites northeast from a region near Stalingrad to carry the satellites over Siberia. The first three complete periods of Sputnik I are shown in Figure 2. In the hour-and-a-half it took Sputnik to go around the world, the earth rotated eastward so that each trajectory was 24° west of the preceding one. A map for a whole 24-hour period is rather confusing, but from an inset over the United States, we see that near any one particular part of this country there are four passes a day (every day as long as the satellite stays up).

The calculation made earlier for a satellite in a circular orbit is a special case, for actually orbits are ellipses with the center of the earth at one focus of the ellipse. By the year 1619, Kepler had worked out the mathematical description of satellite orbits, although it was not until later in the seventeenth century that Newton could give the mathematical reasons why the orbits were ellipses.

Figure 3 shows an elliptical orbit for a satellite with the semi-major axis, perigee and apogee labeled. Kepler showed that for a satellite the cube of the semi-major axis of an elliptical orbit or the cube of the radius of a circular orbit was proportional to the square of the period. In simpler language, for every increase in the period by a factor of 8, the radius must increase by a factor of 4. From the relation given earlier for the period of a satellite whose orbit has a radius of 4350 miles from the earth's center (96 minutes or 1/15 day), and by using Kepler's law, it is an interesting exercise to calculate the distance to the earth's moon whose period is one month (more exactly, the sidereal period is 27.3 days). Somewhat paradoxically it is apparent from Kepler's law that air friction speeds up a satellite by forcing it to drop to a lower altitude where its speed increases. The gain in kinetic energy, naturally, is less than the loss of potential energy, the difference having gone to friction.

How to See a Satellite

At night if you know when and where to look, seeing the Russian satellites is fairly simple. (Explorer is faint and can be seen only with field glasses or telescopes.) You get out several minutes before the satellite's predicted time of appearance, and get away from all lights. To the unaided eye, the third-stage rocket of Sputnik and the "Muttnik" look like medium bright stars moving across the sky in from two to five minutes. Meteors go much faster. Airplanes usually have colored lights and their white lights look yellow by comparison with the stars. Once you have spotted a satellite, you can catch it in field glasses and follow it more readily than without glasses, especially when it gets faint in

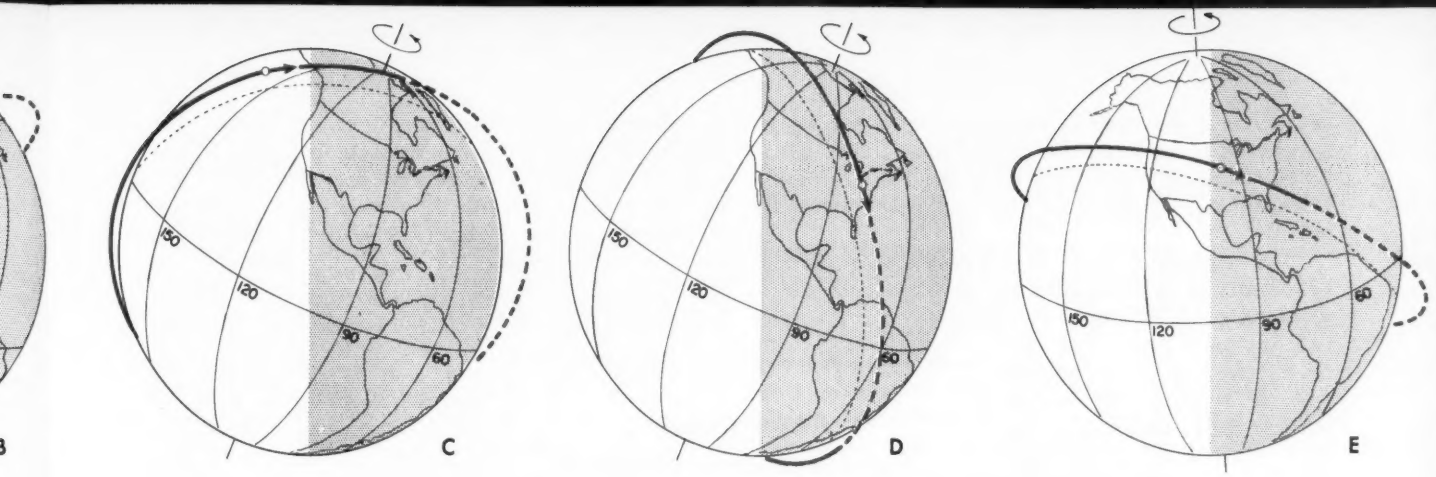


FIG. 4 — See text for discussion of A, B, C, and D. In E a Vanguard orbit early next spring is shown. Its angle of inclination to the equator is 40°, much less than for Russian satellites. Thus as the earth turns under its orbit the Vanguard will never cross any part of Russia except the southern Caucasus. Sunrise passes could be shown only on the other side of the paper. These diagrams were traced from photographs of a globe encircled by an orbit pasted on a piece of plastic, and hence should be reasonably accurate for the late-December to January passes of the second Russian satellite.

the distance or in atmospheric haze. The instrumented satellites themselves are small, hence faint, and can be seen by the unaided eye only under the most favorable circumstances.

The photograph of Figure 1 was taken in Buffalo as the third stage rocket of Sputnik (officially called 1957 Alpha One) passed from the constellation of Bootes to the Big Dipper. When the time exposure was begun, the rocket was moving northeast between Milwaukee and Minneapolis, and at its nearest approach to Buffalo was 425 miles away. The blanks in the trace are caused by a rotating shutter in front of the lens, used to obtain timing marks at one second intervals.

When to See a Satellite

For a satellite to be seen, it must be in the sunlight while the observer is in the black of the night. Therefore the time usually must be about an hour or two after sunset or before sunrise. At a time further from sunset or sunrise, the satellite is likely to be in the shadow of the earth, and hence will not be illuminated. These conditions require that the plane of the orbit be properly oriented **with respect to the sun.**

If the earth were a homogeneous sphere, the plane of the orbit would remain fixed in space with the earth rotating (eastward) inside the orbit. The earth is not a sphere and the gravitational attraction of the 13-mile equatorial bulge tends to twist the plane of the orbit into the equatorial plane. Just as a toy gyroscope suspended at one end from a string tends to tip over but actually turns around slowly (i.e. precesses) instead, the plane of the satellite orbit turns slowly. The effects of this precession together with the yearly motion of the earth around the sun yield a net westward drift of the plane of the orbit, about four degrees per day, so that it takes three months for the orbits of the Russian satellites to shift completely once around the globe.

There are three effects that account for the change in position of the satellite orbit from day to day as seen by an observer **on the earth.** Precession for Russian satellites accounts for a westward drift of approximately 3 degrees per day (depending somewhat on satellite height, etc.); for U.S. satellites this figure is about 5 degrees per day. The motion of the earth around the sun (360° in 365 days) accounts for another westward drift of about one degree per day. Finally, unless the satellite period is an exact sub-multiple of a day, e.g. 90 minutes (= 1/16 day) or 96 minutes (= 1/15 day), or 102.86 minutes (= 1/14 day), it will cross a given latitude earlier or later than on the preceding day. For every 4 minutes of time, the earth turns one degree on its axis. At temperate latitudes, one degree is about 50 miles. Early sightings on the Sputnik I rocket were made while is was crossing the latitude of Buffalo at 6:15 a.m., 6:11 a.m., 6:06 a.m., and 6:00 a.m. E.D.T. on 13-16 October. Since the difference in time of passing between 13 and 14 October was four minutes, the westward motion during that day was about 150 miles (three degrees west for precession, one degree west for the earth's revolution about the sun, and one degree east because the satellite came four minutes early).

Whereas the rocket came four minutes early on 14 October, it was five minutes early 15 October, and six minutes early 16 October. Thus the rocket was speeding up by one minute per day or per 15 periods. From this fact one could calculate that its average distance from the earth was decreasing 2.0 miles per day. Most of the drag on the satellite would be at perigee where it was lowest and the air most dense. Hence on each pass the satellite lost most of its energy in a small region of its orbit, the principal result being that the apogee distance became **four** miles smaller, and the orbit more nearly circular. As the satellite got closer to the earth, spending a larger fraction of time in the region of drag, it came down even faster.

It turns out that there is a regular sequence of occasions or "seasons" when the satellite orbit is properly oriented so that the satellite can be seen for an

interval of a few days before sunrise or after sunset. As can be noted from the map, Figure 2, the initial passes of Sputnik over the USA (and all temperate latitudes) on 4-5 October were not near sunrise or sunset.

The diagrams A, B, C, D of Figure 4 show the left half of the earth illuminated by the winter sun which should be considered to be far to the left. For the right half, the sun has set. The solid red line shows a Russian satellite orbit in sunlight, the broken red line shows the orbit in the earth's shadow so that the satellite is invisible. The dotted line is the path of the earth's surface over which the satellite passes. In A the satellite is going **northeast after sunset** along the east coast of the USA. In B, about an hour and forty minutes later, the satellite orbit is in the same position, but the earth has turned eastward inside the orbit so that the northeast trajectory now crosses the western United States, just after sunset there.

In Figure 4C, two weeks later, the orbit has precessed or turned itself westward, and is oriented so that satellite passes occur either about local noon or midnight, and hence are not visible to anyone anywhere (except in arctic regions). As Figure 4C is drawn, for most of the USA the time is a little after sunset. Passes over the USA would occur only when the globe is turned about 90° from the position shown, that is, at noon or midnight. In Figure 4D two weeks later still, the orbit has precessed further west so that passes are now **southeast after sunset.** The three-month cycle would be completed by passes **northeast before sunrise,** and later **southeast before sunrise.**

It is an interesting fact that a fairly high satellite can be seen in the northern parts of the United States even at midnight in summer, because the height of the earth's shadow (in Buffalo on 21 June) with sunlight coming across the north pole is a bit less than 400 miles.

Manned Satellites

The Russians have already launched a dog into a satellite orbit, and consequently the possibility of launching a man into an orbit is near at hand, though getting him back alive is another matter. Since our Vanguard takes about 1000 pounds of rocket to launch one pound of payload, most of the rocket weight actually being fuel, it is apparent that the energy required to launch a manned vehicle into an orbit will be very great — requiring many tons of fuel even if more efficient rockets are used. Some of this energy used for launching is given to the booster rockets which fall back to earth, and some is lost to air friction on launch. Even so, it is clear that a great deal of energy must be dissipated on the man's re-entry into the atmosphere without boiling him. If all the energy in an orbiting vehicle were converted to heating the vehicle on re-entry, then depending on what it was made of, it would be heated to between 10,000 and 100,000 degrees Fahrenheit. Actually a considerable portion of the re-entry heat is lost to the atmosphere, but it must be obvious that the re-entry problem is a difficult one. Of course there must be some means, too, for the man actually to land without smashing himself to bits. The latter problem is by far the simpler. It appears that some type of ceramic-protected glide-vehicle may work, taking a very long spiral glide into the atmosphere and moving several times around the world.

Since only twice as much energy is required to get a vehicle away from the earth's gravitational field as is required to get it into a near-by orbit, trips around the moon (240,000 miles away) may not be far off. Trips around Mars or Venus (requiring an average of about 1,000,000 miles of travel every day for three years counting the necessary spiraling around in the solar system) are foreseeable, though not yet practical, on the basis of present knowledge and technology.

A Trip Around the Moon

For the trip around the moon, a certain amount of propulsion energy is required to get the vehicle into a near-by orbit. About the same amount of energy is again required to get from the near-by orbit to the neutral point where the earth's and moon's gravity are in balance. Some additional propulsion (actually retarding force obtained by orienting the rocket so that it is going backward) may be useful in producing an orbit close to the moon and around it, and some further propulsion is needed again to get back to the neutral point. These two quantities can be quite small (or zero for a distant orbit about the moon). Returning to an orbit near to the earth then requires retarding forces equal to the propulsion required to get out of the first orbit near the earth. Thus somewhat more than three times as much energy is needed for an orbit around the moon with return to an orbit around the earth, than is needed for an orbit around the earth. At first this factor of three doesn't sound like much, but in view of rocket mechanics, what it really means is that an additional two very large stages would be needed at the bottom end of Vanguard. Perhaps in an instrumented satellite with a radio for transmitting information or a picture one would be satisfied with a return to the vicinity of the earth without slowing into an orbit, either hitting the earth and burning up with a tremendous flash, or swishing past the earth out into the solar system, never to return. Such an alternative would save considerable energy. Because of the re-

Editor's Note

Because of the unusual significance of "Satellite Summary," **Research Trends** is proud to devote this entire issue to Dr. Chapman's article. We point out, however, that the article does not treat research work conducted at this Laboratory, but instead summarizes an extensive subject.

In the Spring issue, **Research Trends** will return to its policy of presenting two timely articles about the Laboratory's technical programs.

quired great tonnage of fuel, chemically powered rockets are not attractive for interplanetary travel.

Space Travel

Interplanetary travel will require a great deal of propulsion, but it can be supplied over an interval of months, for example using energy from a nuclear reactor to accelerate ions (electrically charged atoms) by a high voltage to speeds 100 or more times the speed available by chemical combustion. In a rocket, propulsion effectiveness is determined by the speed with which material is ejected by the exhaust. There is no need (as in the case of a propeller-type aircraft) to have any atmosphere to push against. The amount of material "thrown out the exhaust" by ion propulsion is very small so the force is small (a few hundred pounds) but it can act over months of miles-per-second distance. Such an ion-propelled vehicle would leave from a space station orbiting about the earth. To avoid a weightless feeling for personnel in a manned vehicle, the vehicle could be rotated like a merry-go-round to give an artificial weight from centrifugal force. Taking off from any planet requires great energy over an interval of minutes, and hence a thrust of many tons, and as it appears now, tons of chemical fuel. Consequently it will be a long time before any returns are made from landings on any planet or moon having appreciable gravity. No man will ever move much on Jupiter where he would weigh nearly three times his weight on earth.

Trips out of the solar system to the nearest star, in the southern constellation of Centaurus, more than four light-years or 25,000,000,000,000 miles away, are beyond contemplation for this generation.

The Significance of Satellites

Launching a satellite requires a five-mile-per-second propulsion system and a guidance system. An Inter-Continental Ballistic Missile requires a four-mile-per-second-propulsion system, a guidance system, and a megaton warhead. It is obvious that the Russians have developed the propulsion and warhead. A satellite guidance system yields an error of about 60 miles in altitude for each degree of elevation error and for 100 ft/sec error in speed at final fuel burn out. A 60 mile altitude error is "within bounds" for a satellite, but hardly so for a useful missile. Sputnik proves the Russians have the propulsion, but plausible though it may seem, it does not prove they have an ICBM capability now. Present defenses are of no use against ballistic missiles. No particular technical significance should have been attached to the December or February failures of Vanguard, since perhaps two-thirds of initial missile firings end in failure. We do not know how many failures the Russians had — there is evidence they failed in September — and there was a lengthy interval of no launchings after their second one.

As Columbus was to terrestrial geography, the first satellites are to astronautics with its unlimited potentialities. In this sense the United States must stand in admiration of the Russian achievement. Clearly we are in an age when the impact of science on human affairs never was greater. It appears that we should give more attention (time, effort, and dollars) toward fostering wider appreciation of the influence of science on the citizen, whether that influence is for good or evil. Before we contemplate trips to other planets, let us first be sure we can continue to inhabit our own.

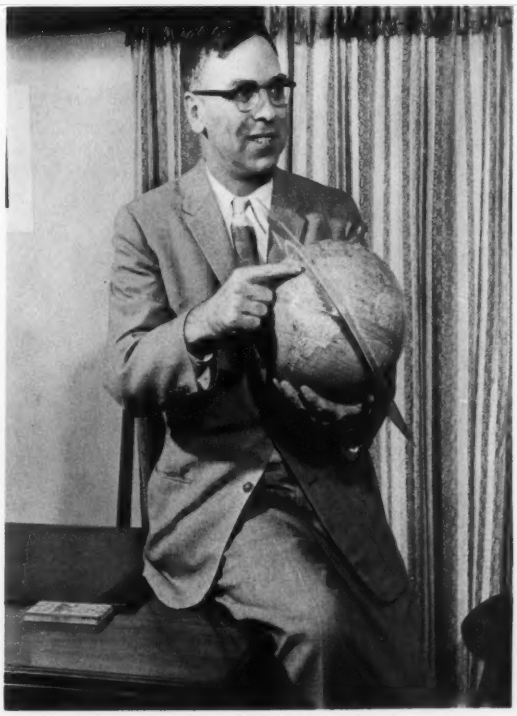
ABOUT THE AUTHOR

DR. SEVILLE CHAPMAN, Director of CAL's Physics Division and author of "Satellite Summary," has been a studious observer of celestial phenomena since boyhood days. His astronomical interests have quickened in the last few months. He was the first person in Western New York to sight Sputnik — on Oct. 13 at 6:15 a.m. — and he has since delivered numerous talks and has been widely quoted in the press on the implications of Russian and United States satellite programs.

Dr. Chapman was born an American citizen in Spain and brought to California when he was six months old. He did his undergraduate and graduate work in physics at the University of California. After receiving his Ph.D. in 1938, he taught at the University of Kansas and later at Stanford University. He came to CAL in 1948 as principal physicist and was shortly advanced to Assistant Department Head and Department Head. In 1957, he was named Director of the Physics Division and Head of its subordinate Applied Physics Department.

In addition to numerous technical papers and articles — many of which have treated his investigations into thundercloud electrification — Dr. Chapman is also the author of the widely read booklet, "How To Study Physics."

His memberships include Sigma Xi, the Physical Society, the Institute of Radio Engineers, the Meteorological Society, and the Institute of the Aeronautical Sciences.



RECENT C. A. L. PUBLICATIONS

The Laboratory invites requests for its unclassified publications as a public service. Supplies of some publications are limited; and those marked with an * may be distributed only within the United States. Please direct your request to the Editor, Research Trends, Cornell Aeronautical Laboratory, Buffalo 21, New York.

"EFFECTIVE AND INEXPENSIVE SLITS FOR TEACHING PHYSICAL OPTICS," Chapman, Seville and Meese, Harold; Reprinted from American Journal of Physics; March 1957; 4 pages.

A discussion is given of how sets of single, double, and multiple slits may be made for use in lecture demonstrations in physical optics courses where each student has his own set of slits through which a source is viewed with the naked eye.

"MEASURING CORONA FROM RADIOACTIVE POINT," Hendrick, Roy W., Jr., Martin, Francis C., and Chapman, Seville; Reprinted from Electronics, Vol. 30, No. 3; March 1957; 2 pages.

Chopper-modulated feedback signal stabilizes amplifier for measuring radioactive corona-point currents in fair weather. Built-in calibration remains practically constant through months of service.

"FLOW DISTURBANCES INDUCED NEAR A SLIGHTLY WAVY CONTACT SURFACE, OR FLAME FRONT, TRAVERSED BY A SHOCK WAVE," Markstein, George H.; Reprinted from the Journal of the Aeronautical Sciences, Vol. 24, Preprint No. 3; 1 page.

An analysis, based on drastic simplifications which should yield order-of-magnitude estimates of the effects to be expected.

"THERMODYNAMIC PROPERTIES OF OXYGEN FROM 2000° K TO 5000° K," Logan, J. G., Jr., and Treanor, Charles, E.; CAL Report BE-1007-A-4; Jan. 1957; 113 pages.

This report presents tables of thermodynamic properties of oxygen at high temperatures, including effects of dissociation and ionization, tabulated at intervals of 100° K between 2000° K and 5000° K.

"SUMMARY REPORT OF VALVELESS PULSEJET INVESTIGATIONS ON THE CAL 10-FOOT WHIRLING ARM," Logan, Joseph, Jr., and Russo, Anthony L.; CAL Report DD-801-A-1; March 1957; 30 pages.

A report summarizing tests of valveless pulse-jet engines for application as helicopter tip-mounted power plants. Major emphasis has been placed upon evaluating the effect of exhaust-to-inlet area ratio and fuel injection system upon engine performance and stability over the test speed range. (Work sponsored by Office of Naval Research.)

"SOME WEATHER OBSERVATIONS WITH A CONTINUOUS-WAVE DOPPLER RADAR," Brantley, James Q., Jr. and Barczys, Daniel A.; Preprint from the Proceedings of the Sixth Weather Radar Conference; March, 1957; 10 pages.

Limited meteorological data are given and where possible these are compared with radar data. Spectra are given for drizzle, heavy rain, and snow under various wind conditions, and a method for determining rate of rainfall from Doppler information is suggested.

"METEOR ECHOES AT ULTRA-HIGH FREQUENCIES," Flood, Walter A.; Reprinted from the Journal of Geophysical Research; Vol. 62, No. 1; March 1957; 13 pages.

It is proposed that, at ultra-high frequencies, underdense meteor echoes have an effective scattering length, which is much less than a Fresnel zone. Consequently, UHF meteoric echoes may be analyzed in terms of Fraunhofer diffraction theory.

"STEAM JET VACUUM PUMPING FOR LARGE ALTITUDE CHAMBERS," Bykowski, Ronald M.; Reprinted from Environmental Quarterly; First Quarter, 1957; Vol. 3, No. 1; 5 pages.

Steam jets have the outstanding characteristic of large-volume capacity at low pressures. This, combined with the advantages of lower first cost, lower maintenance cost, ruggedness, compactness, and ease of operation, makes them eminently suited for use as altitude simulators.

"METHODS OF DETERMINING THE THERMAL CONDITION OF GLASS ELECTRON TUBES," Welsh, James P.; Reprinted from the Proceedings of the 1957 National Conference on Aeronautical Electronics; 7 pages.

Studies have shown that the temperature of the glass surrounding vacuum tube elements is not always a reliable index of their thermal condition. This paper explains the thermal details and reasons for this finding, together with more reliable methods of ascertaining the degree of cooling.

"FLUTTER MODEL TESTING AT TRANSONIC SPEEDS," Targoff, Walter P. and White, Richard P., Jr.; Paper presented at the Institute of the Aeronautical Sciences; Jan. 1957; 29 pages.

A discussion of design and construction of flutter models for wind tunnel testing, and descriptions of static vibration and flutter tests.

"A RESISTANCE THERMOMETER FOR TRANSIENT SURFACE TEMPERATURE MEASUREMENTS," Vidal, Robert J.; Preprint of paper presented at the American Rocket Society Meeting; Sept. 1956; 45 pages.

This preprint describes instrumentation developed for the measurement of aerodynamic heat transfer to a model in a shock tunnel.

"DIFFERENTIAL DELTA THREE — A METHOD FOR IMPROVING THE LONGITUDINAL STABILITY OF THE TANDEM HELICOPTER," Adler, Abraham C.; Preprint of paper presented at the Institute of the Aeronautical Sciences; Preprint No. 693; Jan. 1957; 31 pages.

The term differential Δ_3 has been devised to describe the use of a differential in pitch-cone coupling between the two rotors of a tandem helicopter. This paper presents a discussion and brief theoretical analysis of differential Δ_3, the effects on the angle of attack stability, and the control problems associated with the use of this type of system.

"POWER SPECTRUM MEASUREMENTS BY NUMERICAL METHODS," Fleck, John T., CAL Report No. 85-440-1; Jan. 1957; 11 pages.

For many processes it is impractical to determine harmonic content by the use of a wave analyzer. One solution is to record the output and analyze it numerically to determine the harmonic content or power spectrum. This method of analysis is described and an example is given.

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